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Maturity Standards for Harvesting Bartlett Pears for Eastern Shipment

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MATURITY STANDARDS FOR HARVESTING BARTLETT PEARS FOR EASTERN SHIPMENT

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Bartlett pears are grown in California under a wide diversity of climatic conditions, ranging from the cool, coastal districts to the hot, dry, interior valleys. The commercial picking season, or the time of ripening in the various districts, extends over a period of approximately three months. Fruit designed for canning and drying may be somewhat more mature before harvesting than that which is to be shipped as fresh fruit. Pears differ from most other deciduous fruits, however, in that even when intended for immediate use, they should not be allowed to become fully ripe on the tree. Much better quality is obtained if they are harvested a number of days in advance of the time at which they are desired. Extremely early picking, frequently practiced with Bartlett pears which are to be shipped as fresh fruit, is on the other hand, also very detrimental to the development of good quality.

While some growers realize the advantages of having their fruit well matured before starting to harvest, others, particularly in the earlier districts, consider that the higher prices received for the first few shipments of the season justify premature picking. This early harvesting, practiced at first by only a few growers, has now become competitive, and a considerable proportion of the first shipments of Bartlett pears from the early sections of California are so immature that the normal dessert quality of the fruit fails to develop.

The need for some standard to regulate picking practices has been recognized for several years. A standard which would be equitable and suitable to all districts of the state must, however, of necessity be based upon a knowledge of the variations of fruit ripening in different districts, and also upon a reliable maturity test.

After several years' investigations by the Division of Pomology, University of California, it is believed that sufficient information has been collected on the different types of Bartlett pears produced, and on their manner of ripening in the different districts, so that practical methods of determining maturity can be offered. The two tests of

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color and firmness, herein described, form the basis of the maturity standards recently adopted as a part of the California Fruit, Nut, and Vegetable Act. After a brief discussion of some of the experimental work, suggestions are given for making these tests.[2]

MATURITY DEFINED

The word "maturity" is difficult to define with exactness. The development of pears is the result of certain changes, both physical and chemical in nature. Since these changes are continuous, it is apparent that the term "mature" can relate only to some arbitrary period or stage of development in the life of the fruit. From the standpoint of harvesting, pears and other fruits are therefore considered *mature,* or ready for picking, when they have reached a sufficient degree of development from which the various ripening changes, mentioned above, will proceed to satisfactory completion when the fruit is removed from the tree. Pears picked after their growth is practically completed and the other changes are well advanced, will, unless kept continuously or too long at cold storage temperatures, eventually become soft and assume their characteristic flavor. Fruit picked prematurely, on the other hand, either will fail to ripen or will ripen with poor texture and flavor.

FRUIT DEVELOPMENT AND THE RIPENING PROCESSES

Increase in size and a gradual transition in color from a green to a yellowish-green, followed by a greenish-yellow and finally by a yellow, are the most obvious changes in the development of Bartlett pears. Growth begins with the fertilization of the flower and continues as long as pears are usually allowed to remain on the trees. Color changes are more closely associated with the final stages of development, or ripening. In most instances, color changes are more marked after harvesting than before. Although softening of the flesh is also more marked after harvesting, yet, when measured by mechanical means, very noticeable changes in texture or softening are found to begin considerably in advance of any change in color. Another physical change, but one not so well recognized by growers, is the change in texture and thickness of the skin. As the fruit approaches

[2] With one exception, only the data secured in 1928 are included here since those for 1925 and 1926 have been summarized and will be presented in a forthcoming publication from the United States Department of Agriculture, "Investigations on Handling Bartlett Pears from the Pacific Coast Districts."

its full size, the lenticels or breathing pores have developed beneath them a corky tissue which reduces transpiration. Fruit picked before the lenticels have developed this tissue usually shows excessive shriveling.

Accompanying and following these physical changes in development are also those in chemical composition. The most important of these are changes in the percentage of solids, sugar, acid, pectin materials, and esters. As pears ripen there is a gradual increase in sugars and other soluble solids, and in the flavoring oils or esters. The acid content and insoluble pectin materials decrease. These changes begin while the fruit is still on the tree but are most marked in the later stages of ripening. Attempts, therefore, to measure these chemical changes prove of little value as an index for harvesting. Moreover, making any such determinations under field conditions is attended with considerable difficulty.

OUTLINE AND SCOPE OF THE INVESTIGATIONS

A few preliminary tests on the maturity of Bartlett pears were made in 1924 in connection with the studies on plum maturity in Placer County.[3] In cooperation with the United States Department of Agriculture in 1925 and 1926 this work was somewhat enlarged and included not only Placer County but also the Sacramento River District, the Santa Clara Valley, and Nevada, Lake, Solano, and Sonoma counties. The investigations included both field and laboratory tests. During 1927 rather critical laboratory studies were conducted with fruit from four individual orchards located in Placer and Nevada counties, in the Sacramento River district, and in the Santa Clara Valley. As the work thus far seemed to clearly indicate that firmness and color changes offered the only practical maturity index for harvesting Bartlett pears, the work during 1928 was confined to a more extensive study of these two changes, and to correlating them with dessert and keeping quality. In an endeavor to have the results representative of the pear growing sections throughout the state, samples were collected from over 200 individual orchards located in 14 different counties or districts.

[3] Allen, F. W., J. R. Magness, and M. H. Haller. The relation of maturity of California plums to shipping and dessert quality. California Agr. Exp. Sta. Bul. 428:1–41. 1927.

COLLECTING AND HANDLING OF SAMPLES

In most instances the different districts were visited at weekly or 10-day intervals, beginning at the time of, or slightly preceding, the first commercial picking. Throughout the picking season, samples were collected either directly from the trees or from commercial lots as they were brought into the packing houses.

Each sample contained approximately 25 specimens which, after the beginning of commercial harvesting, represented as nearly as possible the fruit which would be, or had been, picked on that day. From this sample, ten pears were selected for pressure test determinations, their size and color having first been recorded. The remainder of the sample was taken, or in a few instances shipped, to the University Farm at Davis, where it was held for twelve days under a temperature of 48° to 50° Fahrenheit and then removed to a temperature of about 75° F for ripening. After removal from this 12-day storage period at 50° F (representing the time and the approximate temperature to which fruit in the upper half of a refrigerator car would be subjected in transit to New York) record was made as to the number of days each sample required to ripen, the quality of the fruit when ripe, and the number of days it remained in good marketable condition. The cause of its final discard was also noted. These data for each sample were recorded with the pressure test of the fruit picked on different dates.

METHOD OF DETERMINING COLOR, FIRMNESS, AND QUALITY

Color determinations were quickly and accurately made by comparing the color of the fruit with a color chart shown opposite page 16. For greater accuracy and convenience in experimental work, the different shades of green or yellow were simply designated by number. No. 1 corresponds to the color in the chart designated as green; No. 2 corresponds to light green; No. 3 to yellowish-green, and No. 4 to yellow. Where the color of the pears appeared to be between two shades, fractional numbers were used. The diagram, figure 2, also uses this manner of designation.

Firmness of the fruit was recorded by the use of a pressure tester which measured in pounds the pressure required to force a plunger point $\frac{5}{16}$ inch in diameter into the flesh of the fruit to a depth of $\frac{5}{16}$ of an inch. Ten pears were used in each test, and each fruit was tested twice, once on each side. The average of all of these readings

constituted the record of the firmness of the sample. For the sake of greater uniformity and more accurate determination of the firmness of the flesh, the skin was first removed from the points tested.

The dessert quality of these samples was determined by cutting and sampling several specimens on the day on which they appeared to have reached prime eating condition. In most instances the quality recorded represented the judgment of several individuals.

The keeping quality was determined by the number of days required for the fruit to ripen and the time it remained in good marketable condition after ripening.

PRESENTATION OF RESULTS

Fruit from different orchards showed certain variations, but the following tables (1 to 13 inclusive), which summarize the tests conducted in certain of the more important districts will serve to give a very good idea of how the fruit ripened. Various comments and notes on the color, firmness, and quality of the fruit accompany each table. Figure 1 shows graphically the general trend of softening of Bartlett pears in certain districts during 1928, while figure 2 indicates the color and shows the pressure of all samples collected after the beginning of the 1928 commercial picking season.

TABLE 1

Maturity of Bartlett Pears, 1928; Summary, Sacramento River District

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
6/21*	26.2	1½–2	6.6	1–3	Poor	Fruit ripened imperfectly and decidedly lacking in flavor. Shriveled quickly.
6/30	23.5	1½–2	4	3	Fair	Flavor insipid. Some shriveling.
7/10	22.0	2	4	4	Fair to good	Fruit softened normally.
7/21	19.5	1½	4	4	Good to very good	
7/31	20.0	2–2½	3	5.5	Very good	

* Small quantities of fruit being shipped on this date.

The figures in table 1 represent a total of 45 samples, obtained from 19 different orchards, and approximately 720 tests. The average pressure test from all samples, as well as the tests from individual orchards, show a very significant and consistent decrease in the firmness of the fruit throughout the season. The fact that the last picking

is fractionally more firm than the one 10 days previous is due both to sampling and to other factors to be discussed later. The fruit from the Sacramento River district did not attain good quality until it had softened to 22 pounds and had attained a No. 2 color. To be of good quality with less color it should register as low as 20 pounds. Early-picked samples often ripened unsatisfactorily, the lenticels remaining green, the texture tough, and the flavor insipid, or acid. After reaching a stage designated as ripe, the fruit shriveled very rapidly. Late pickings ripened in two to three days less time than the more immature fruit, but possessed good keeping quality for from three to five days. The fruit picked between July 20 and 30 possessed decidedly the best quality of any. It could have been shipped even somewhat more mature.

TABLE 2

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, LOOMIS, NEWCASTLE, AND AUBURN DISTRICTS

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/2*	23.9	1½	4	3	Fair	Somewhat insipid, slight shriveling.
7/12	22.2	1½	3–4	4–5	Fair to good	Fruit ripened satisfactorily.
7/23	20.5	1½–2	3–5	3–5	Fair to very good	
8/8	20.5	2–2½	3–4	4–5	Good to very good	
8/14	19.3	2–3	4.5	6	Good	

* Fruit being picked from a few orchards in the vicinity of Newcastle, 1000–1200 feet elevation.
‡ Fruit being picked at Auburn, 1300–1500 feet elevation.

Data from the Loomis-Newcastle-Auburn districts of Placer County represent 55 samples or approximately 900 tests from 27 orchards. The average pressure tests from all three districts show the characteristic softening as the season advanced. In one or two instances, however, individual orchards on Japanese rootstock at Loomis and Newcastle failed to show any material softening during the later part of July and early August. Several samples picked at 24–25 pounds pressure ripened with poor quality. In general, however, little fruit was picked from this district before it was sufficiently mature to ripen with fair quality. In several individual orchards the fruit lacked flavor throughout the season. No effect of continuous irrigation in one orchard was noticed on the keeping quality of the fruit. The last commercial pickings in the vicinity of Auburn were not made until September 1.

TABLE 3

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, GRASS VALLEY DISTRICT

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/28*	20.7	2½	3	4.2	Fair	No wilting with any samples.
8/8	20.2	1½-2	4	3.6	Good to very good	
8/13	19.0	2	2.6	5.6	Fair	A few samples developed slight scald.
8/18	19.8	2-2½	4	3.6	Fair	
8/27	18.3	2½	2‡	5.4	Fair to very good	

* Three to five days before the beginning of commercial picking.

‡ In addition to 11 days at 50° F these samples were held for 22 days at 32° F before ripening.

During the 30-day period, July 28 to August 27, 22 samples were collected in the Grass Valley district from 12 different orchards. The individual tests numbered 350. The general results were similar to those obtained in the Newcastle-Auburn section, but with the harvesting dates somewhat later. The fruit did not possess good quality until it had softened to 20 pounds.

TABLE 4

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, PLACERVILLE DISTRICT

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/16*	22.0	1½	4	3-5	Poor to fair	Fruit insipid and a few samples testing as high as 24 pounds, wilted.
8/9	20.7	2	4	5.2	Fair to very good	Normal ripening.
8/15	18.8	2½-3	3.4	4.7	Very good.	
9/11	14.5	2-3	2	4.4	Very good.	

* Approximately one week before the beginning of commercial picking.

Three hundred and eighty-four tests, comprising 24 samples from 20 orchards were secured from the Placerville district. In general this fruit is similar to that from Auburn and Grass Valley—moderately firm but showing consistent softening, from 22.8 pounds on July 16 to 14.5 pounds on September 11. Fruit from this district did not develop good quality until it was of a good No. 2 color and tested under 21 pounds. Fruit harvested September 11 at 14.5 pounds ripened in two days after arrival but held up reasonably well.

TABLE 5

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, ORANGEVALE DISTRICT, SACRAMENTO COUNTY

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
6/26	27.8	1½-2	6	.....	Poor.....	Fruit lacked flavor or was acid or bitter. Wilted badly.
7/5*	23.7	2	7	.....	Poor to fair.....	Samples showed considerable variation in quality.
7/13	24.1	2	4	.....	Fair.....	
7/24	22.7	2	4	3.8	Fair to good.....	
7/28	20.1	2½	4	5	Good to very good..	

* Beginning of commercial pickings.

Samples in the Folsom-Orangevale district were secured from five different orchards, two of which secured very little irrigation. All of the fruit from this district was very firm and well colored, characteristic of that from districts of high temperature and low humidity and where many of the trees are on Japanese rootstock. From two very dry orchards, the fruit picked during the middle of July was slightly firmer than that picked 10 to 12 days earlier. For approximately two weeks during the middle of the season, no change in pressure tests were noticeable. The total softening over the 30-day period, however, amounted to 7.7 pounds. Until late in the season most samples ripened with only fair quality.

TABLE 6

MATURITY OF BARTLETT PEARS, 1928; SUMMARRY, LAKE AND MENDOCINO COUNTIES

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/14	22.5	1	6	4.0	Poor to fair.....	Fruit shriveled and inspid or of undesirable flavor.
7/20*	20.6	1½-2	5	6.0	Good to very good, mostly good.	
8/4	23.0	1½-2	4	4.5		
8/18	23.0	2	4	4.3	Fair to very good, mostly good.	
8/27	19.4	2-2½	5	4.6	Fair to very good, mostly good.	

* Commercial picking did not begin until a week or 10 days later.

Nearly 1000 tests were made and 58 samples collected from 26 orchards in Lake and Mendocino counties. The first samples of fruit

were secured from five Lake County orchards on July 14, some two weeks before commercial picking started. This fruit, although testing 22.5 pounds, was still of a No. 1 color and the quality when ripe was poor. On July 20, additional samples were secured from the same orchards, the fruit having dropped in firmness to 20.6 pounds and having gained to a No. 2 color. The quality was good. Early pickings were made in some orchards previous to the third samples collected August 3–4. Pickings made August 4 and 18 averaged 23 pounds or slightly higher than with the earlier pickings.

In general, the pears picked during the forepart of the season were grown on French rootstock and were distinctly different in color, shape, and texture from those picked later. Fruit grown on Japanese stock, while attaining a No. 2 color early, remained very firm, and no fruit was picked commercially until August. A mixture of these two types of pears is believed to be largerly, but not entirely, responsible for the higher pressures in the middle of the season. Other possible causes suggested by growers are the exceedingly hot weather during July and the possibility that the firm fruit may have come from a late bloom.

TABLE 7

Maturity of Bartlett Pears, 1928; Summary, Vacaville District

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/6*	24.7	1½	6	3	Fair	Not of high flavor. A few samples showed some shriveling.
7/14	22.5	1½-2	4	3.5	Fair to good.	
7/26	20.8	2	3	5.4	Very good.	

* Commercial picking started approximately July 1.

Samples of fruit from 14 Vacaville orchards showed very consistent softening during the month of July. The rate of softening, however, was characteristic of the warmer, drier sections. Fair to good quality was secured at 23 pounds, while very good quality was secured at 20 to 21 pounds.

Twenty-nine samples from six orchards were secured from the Monticello district. With a dry, hot, climate and the trees on Japanese rootstock without irrigation, the fruit is exceedingly firm and late in ripening. It also attains a high color. Beginning with a 26.4 pounds pressure, July 15, the fruit had softened only to 21.6

pounds by September 6. By August 6 all samples were showing a No. 2 color and ripened with good quality. The rate of softening after August 15 was scarcely measurable.

TABLE 8

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, MONTICELLO DISTRICT

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/15	26.4	1½	4	1-2	Poor	Fruit shriveled and became spongy as soon as ripe.
7/30	26.2	1½-2	4.7	3.3	Fair	Fruit similar to previous sample.
8/6*	23.9	2	4	4.9	Good.	
8/15	22.9	2½	4.8	3.8	Mostly good	Quality of samples rather variable, some being of undesirable flavor.
8/21	21.9	2½	4	5.8	Fair to good	
9/5	21.6	1½-2	5	4	Good to very good	
9/11	21.8	3	4	6	Good to very good	Sample from one orchard only.

* First commercial pickings. One orchardist delayed picking until September 1.

TABLE 9

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, SUISUN DISTRICT

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/6*	22.5	1½-2	5	2	Poor to fair	Most samples were discarded because of a general breaking down and discoloration of the flesh around the core.
7/14	22.5	1½-2	4	2.6	Fair to good	Slight discoloration of the flesh in some samples.
7/26	19.8	2	3	3.6	Good to very good	No discoloration.

* Beginning of commercial picking.

In the sampling from the Suisun district no difference in color or firmness is shown between the first two samples, largely because the early fruit was picked as fast as it ripened. The quality, however, had apparently improved slightly. During the next two weeks the fruit softened to 19.8 pounds and for the most part ran good to very good in quality. In color few samples were rated as high as No. 2. The above figures represent the samples from 14 orchards and approximately 300 individual tests.

TABLE 10

Maturity of Bartlett Pears, 1928; Summary, Contra Costa County

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/9*	24.0	1–1½	3.7	2	Poor	Insipid flavor and flesh becoming brown around the core. Some samples spongy.
7/17	23.6	1½–2	3	4.3	Poor to fair	
7/24	22.3	1½–2	4	4	Fair	Slight browning, the flesh becoming soft and mealy.
7/30	21.4	1½–2	3	5 5	Good to very good	No browning observed.

* Picking began, generally, on this date.

The extent of the work in Contra Costa County comprised 526 tests or 33 samples from 25 orchards.

The color of the fruit in this section made little change throughout the picking season. The early pickings were invariably of poor flavor, and good quality was not secured until the end of the season. The keeping quality of this later picked fruit was also superior to that of the earlier pickings.

TABLE 11

Maturity of Bartlett Pears, 1928; Summary, Napa County

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/14*	24.3	1½–2	4	2	Poor	Fruit tasteless. Slight browning of the flesh in most samples.
7/30	21.8	2–2½	4	3.1	Fair to very good, mostly good.	Slight browning of flesh in a few samples.
8/2	21.0	2–3	2.4	5.7	Good to very good	Fruit ripened quickly but kept well.

* Beginning of commercial picking in vicinity of Napa and Vineburg.

Twenty-four samples and 384 tests were made from 17 orchards in Napa County. Fruit was secured from seven individual orchards adjacent to Napa on July 14 and July 30. On August 2 additional samples were secured near Vineburg and then north of Napa toward Mendocino County. Samples adjacent to Hopland where pickings were just starting were somewhat firmer (approximately 23 pounds) than around Napa. This fruit, however, ripened with good quality, while most samples testing between 23 and 24 pounds from Napa did

not. Little fruit was picked from Napa when firmer than 23 pounds, but practically all the crop was harvested within a period of two weeks. The Napa fruit did not keep quite so well as that from orchards further north.

TABLE 12

MATURITY OF BARTLETT PEARS, 1927 AND 1928; SUMMARY, SALINAS AND SANTA CLARA VALLEYS

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
7/27/27	21.3	1½-2	4	2	Poor to fair	Fruit shriveled, and flesh became brown.
8/ 4/27*	19.4	2	3	3	Poor to fair	Rather insipid. Slight browning of flesh.
8/10/27	18.0	2	2	2	Fair	Slight browning when fully ripe.
8/23/27	16.0	2½	2	2	Fair to good	
7/24/28‡	22.9	1½	2.8	1.8	Poor to fair	Fruit ripened quickly and flesh became soft and brown.
8/11/28	20.0	2	2.0	1.0	Fair.	

* First commercial picking on this date.

‡ Early pickings from the Santa Clara Valley were made on July 18.

General averages secured in the Santa Clara Valley in 1926 indicated that fair quality was not attained until the fruit had softened to 21.5 pounds and that good quality was not present when it was firmer than 20 pounds. The fruit in 1927 from an individual orchard was not of fair quality until it reached 18 pounds. Averages for 1928 are however, slightly higher. All samples remained in prime condition only a relatively short time.

TABLE 13

MATURITY OF BARTLETT PEARS, 1928; SUMMARY, ANTELOPE VALLEY

Date harvested	Pressure test reading (pounds)	Color index	Days to ripen after 12-day 'shipment' period	Days remaining marketable after ripening	Quality when ripe	Remarks
8/8*	21.6	2	4.0	3	Good	Miscellaneous sample from several orchards. Fruit of poor quality and delayed in shipment.
8/14	21.7	2	4.0	2	Good to very good	Miscellaneous lot. Delayed somewhat in shipment.
8/23	19.9	2	4.0	3.8	Very good.	
8/29	19.2	2	3.2	5	Fair to very good	Quality variable.

* Commercial picking began August 1.

All samples from the Antelope Valley section were collected by the state fruit inspectors and shipped to Davis by express. Several days elapsed between the time of picking and storing. Most of the fruit had the characteristics of having been grown on Japanese rootstock. It had attained a No. 2 color at the beginning of the picking season and in all probability did not test over 23 pounds when picked. All samples ripened with good quality. Little difference was noticed in the keeping quality of the different lots.

CHANGES IN FIRMNESS AND COLOR

Color changes.—Although more apparent to casual observation, the color change in Bartlett pears previous to harvesting is, in most districts, less when actually compared with a color chart than the change which takes place in firmness as shown by the pressure tester. In a few sections the fruit may be allowed to remain on the trees until it attains a distinct yellow cast, but in the earlier districts the greater part of the total crop is harvested as soon as there is any "breaking" or changing from the original green color. Picking previous to this time will, perhaps without exception, result in fruit showing considerable shriveling and having very poor dessert quality.

Softening changes.—Using the pressure test data shown in the previous tables, the general trend of softening of Bartlett pears is expressed graphically in figure 1.

Figure 2 illustrates the relative color and the firmness of nearly 350 samples secured in 1928 after the beginning of commercial picking. The diagram clearly shows, that despite several factors influencing the rate of coloring and of softening, both increase as the season advances.

Considering the usual rate of coloring and softening in the earlier districts, and using present color and firmness standards as indications of the earliest dates at which Bartlett pears should be harvested, it is estimated that the sample of fruit testing 29 pounds on June 20 was harvested at least two weeks in advance of its proper maturity. Some 50 or 60 other samples were picked from 3 to 10 days before the time when the fruit could be expected to ripen with even *fair* quality. All samples not having a strong No. 2 color should preferably not have been harvested until the firmness was 23 pounds or below.

The average of the results of 1928 with those of former seasons shows that pears grown on French rootstock under moderate temperatures and humidity conditions, and with a normal supply of soil

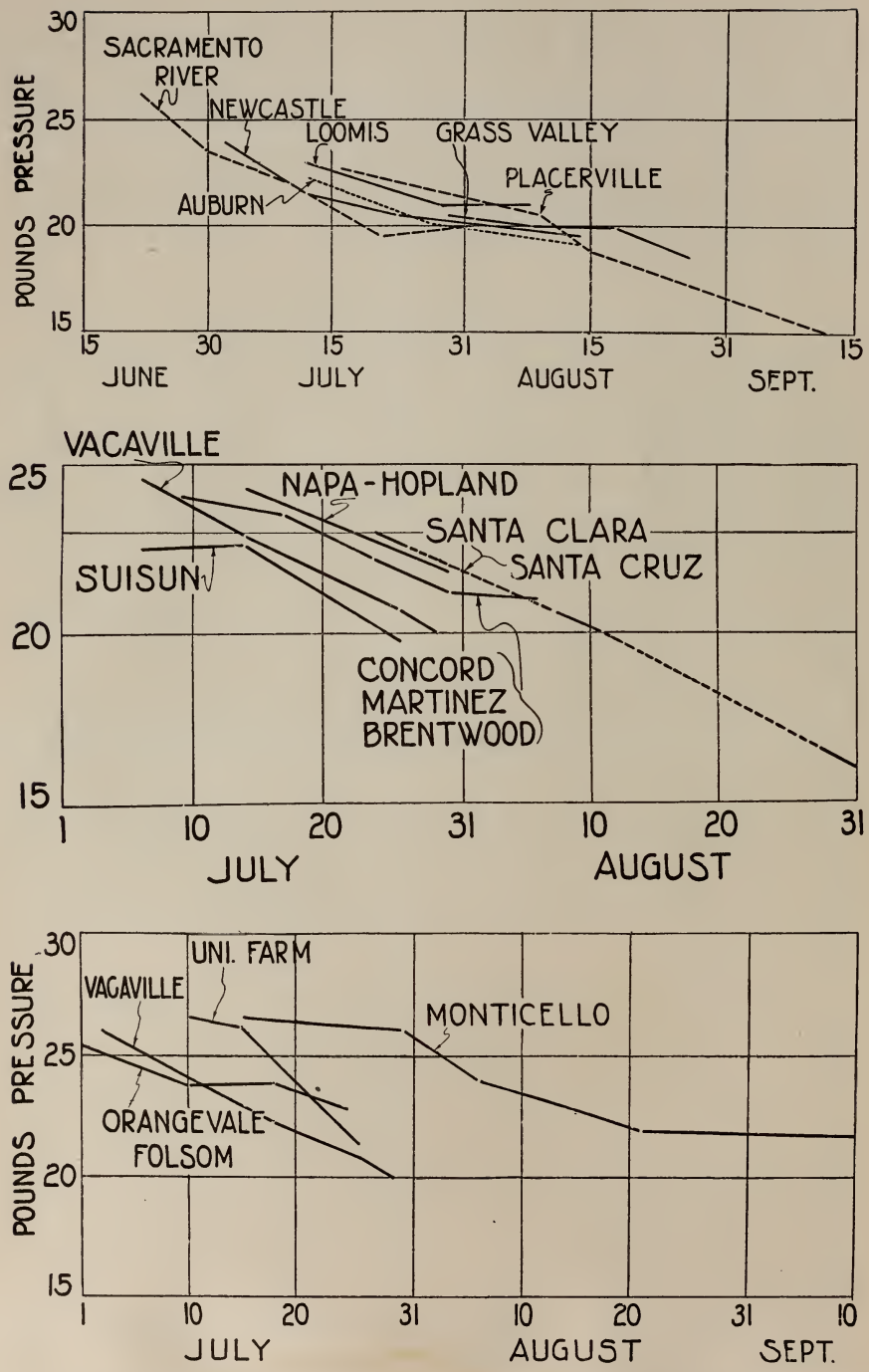


Fig. 1.—Approximate general trend of Bartlett pear softening during 1928.

STANDARD COLOR CHART

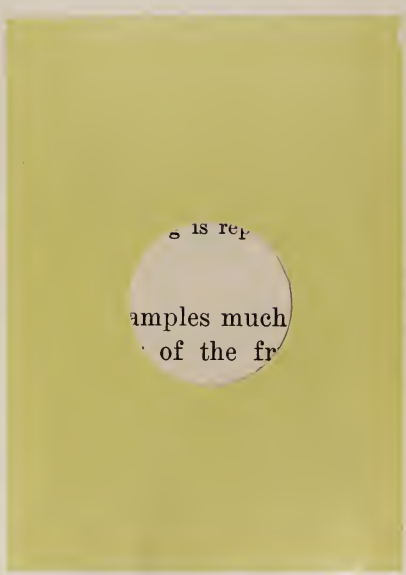
MATURITY OF BARTLETT PEARS

CALIFORNIA STATE DEPARTMENT OF AGRICULTURE

NO. 1. GREEN

NO. 2. LIGHT GREEN

NO. 3. YELLOWISH-GREEN



NO. 4. YELLOW

CAVILLE

AVILLE

LLO

moisture, soften, between the time of the earliest and last pickings, from two to three pounds every 10 days. In a few districts and in individual orchards, softening may be from three to four pounds; in other districts, where many of the trees are on Japanese rootstock, there may be periods of from 10 days to two weeks during the ripening season when there is little if any softening. In individual orchards a given lot of fruit at a certain date may even be firmer than a sample secured from the same tree a week or 10 days previous.

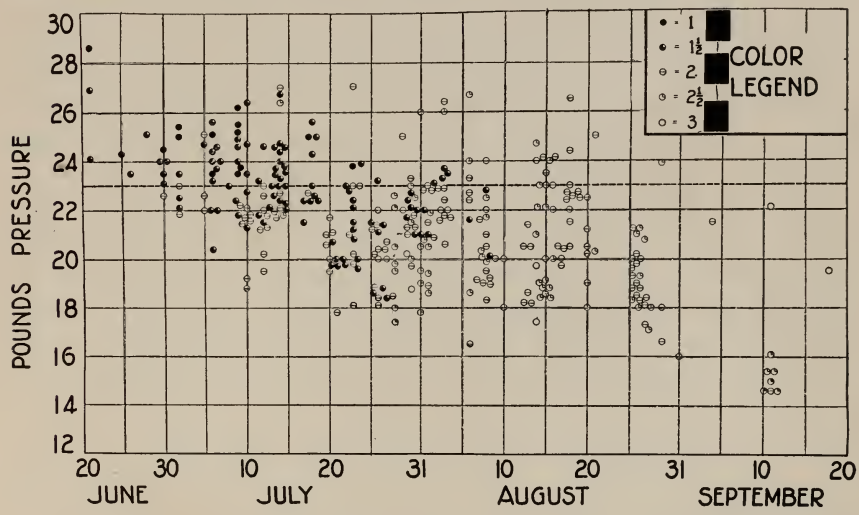


Fig. 2.—Scatter diagram indicating the relative color and showing the firmness of 339 Bartlett pear samples secured during 1928, after the beginning of commercial harvest. Each sample, or dot, represents 15 to 20 individual tests on pears taken from 200 orchards in 14 districts. The darker dots represent the darker shades of green. For those familiar with mathematical calculations of correlation coefficients, the relation between softening and the advance in the season is represented by $r = .554 \pm .026$. The general trend of softening is represented by $y = 24.81 - .7614x$.

This may be explained by the fact that between samples much of the riper fruit had been picked, or that the firmness of the fruit was actually influenced by climatic factors.

Influence of Climate and other Factors.—The amount and rate of both softening and coloring seem to be influenced by, or at least associated with, the temperature and humidity of the district and the relative length of time during the development of the fruit that the trees may suffer from a shortage of available soil moisture. In cool districts, the pears tend to be somewhat softer and of greener color, while in the hotter districts with less humidity, the fruit becomes more yellow before softening. This is seen in comparing fruit from

the Vacaville district with that produced in the Santa Clara Valley. In one season, representative samples from the former showed a color of 2 to 2½ on July 1 and an average pressure test or 23.6 pounds. The fruit from the Santa Clara Valley did not attain an equal color value until July 26, when it tested only 16.7 pounds. Similar, or even greater differences have been noted in comparing fruit from Lake County, the Orangevale-Folsom district in Sacramento County, and the Monticello district in Napa County, with that from the Suisun Bay or Sacramento River districts. Similar conditions are reported by Hartman[4] during periods of drought in Oregon. Under such conditions it is believed that the increase in pressure test readings resulted from loss of turgidity in the fruit. Climatic factors are therefore of first importance in determining firmness and color changes and the general season of harvesting.

Much of the fruit grown in the hotter, drier districts of California is produced on Japanese rootstock, and for the most part is characterized by greater color and firmness than that produced on French stock. The harvesting of such fruit is frequently delayed until that which is softer, but greener in color, has been picked. Even with this delay, much of the fruit will be several pounds firmer than that from the French stock. Pressure test readings of from 22 to 25 pounds or, in some instances higher, may be expected even later in the season. Fruit of a distinct yellow color, however, regardless of its firmness, may safely be picked without fear of wilting.

The firmness of pears from trees on Japanese rootstock is frequently further intensified by the physiological trouble known as "black-end." Although in the later stages of this trouble the disease is characterized by a blackening of the blossom end of the pear, in the earlier stages it may be recognized only by a somewhat abnormal swelling of the blossom end of the fruit and by the very hard, often woody flesh. This condition frequently results in considerable variation in the firmness of this type of fruit.

It seems probable that the type of soil, the exposure of the orchard, the method of handling the trees, the size of the crop, and the proportion of the crop previously picked may have some indirect influence at least upon the coloring and softening of the fruit. Experimental work to determine these points has, however, been limited.[5] Factors influencing the pressure test readings on individual fruits will be mentioned in connection with the use of the pressure tester.

[4] Hartman, Henry, "Studies relating to the harvesting and storage of apples and pears." Oregon Agr. Exp. Sta. Bul. 206:14. 1924.

[5] Hartman gives some data on the last named possible influence in Oregon Exp. Sta. Bul. 206:12–13. 1924.

THE CORRELATION OF COLOR, FIRMNESS, AND QUALITY

Dessert quality.—In an attempt to correlate the dessert quality of the fruit when ripe, with changes in firmness and color previous to harvesting, evidently no single standard can be set up which will apply to all districts. Bartlett pears as produced in California may, however, be classified in three rather large goups: (1) the relatively soft, green colored pear of the coastal and bay regions, (2) the very firm, highly colored pear found in certain sections of the interior valley where high temperatures, low humidity, and often a shortage of water prevail, and (3) the rather intermediate type of fruit which represents the largest proportion of the total crop.

Classifying the fruit in this manner, the determination of firmness or color standards is relatively easy. In those sections where the fruit is of very firm to tough texture and of high color, color furnishes the most satisfactory index for harvesting. In other districts, the firmness of the fruit is the most definite criterion of its future quality. With these alternative guides for harvesting, tables 1 to 13 inclusive, as well as other previous work, may be summarized as in table 14.

TABLE 14

Reccommendations for Harvesting Bartlett Pears

Location where grown	To secure fair quality		To secure good to best quality	
	Maximum pressure test (pounds)	Minimum color	Pressure test (pounds)	Color
Coastal and bay districts	22	1½	20–17	1½–2
Interior valleys and foothills with irrigation	23	1½–2	20–15	2–2½
Hot, dry interior districts with little or no irrigation	25	3	25–20	3–4

Shipping quality.—It is recognized that if fruit is allowed to remain on the tree too long before harvesting it will have poor carrying quality. Pears picked very early likewise fail to carry well. Immature fruits, while not becoming yellow or soft in transit, have a tendency to shrivel and become loose in the package. When exposed for sale such fruit presents a wrinkled appearance and often shows severe bruising. If, however, the fruit is sufficiently mature to ripen with good dessert quality it will carry well, and remain in good condition after arrival as long or longer than that picked earlier. Best shipping quality has been found, therefore, to be very closely

associated with that stage of maturity giving good dessert quality. Bartlett pears picked when at the lowest pressure under "good to best quality" may be considered slightly too mature for long distance shipments. Fruit arriving fully ripe is not desired by the eastern trade, and the returns to the grower are likely to be somewhat discounted. Properly handled, however, such fruit should meet with ready sale on local markets.

REQUIREMENTS FOR HARVESTING

Realizing the need of some definite measure of maturity and of standardizing picking practices of Bartlett pears, particularly the early shipments, representative growers have accepted the following definition and restrictions relating to maturity. The California Fruit, Nut, and Vegetable Act of 1929, regulating the movement of fresh fruit shipments, includes the following paragraphs:

Bartlett pears shall not be considered mature unless at the time of picking the color of the skin between the lenticels is of a noticeably lighter green than that of the lenticels themselves and the average pressure test of not less than ten representative pears of the lot does not exceed twenty-three pounds; provided, however, that if pears show a distinctly yellowish-green color at the time of picking they shall be considered mature if the average pressure test of not less than ten representative pears of the lot does not exceed twenty-five pounds; provided further that pears which show a distinctly yellow color at the time of picking shall be considered mature regardless of the pressure test.

The pressure test shall be determined by means of a fruit pressure tester measuring in pounds the force required to push a rounded plunger five-sixteenths of an inch in diameter into the flesh of the fruit to a depth of five-sixteenths of an inch. The skin from the areas tested, but little of the underlying flesh, shall previously be removed. Two such determinations are to be made on each specimen selected as a sample and the average of all individual readings from the sample shall be considered as the pressure test of the lot. Pressure test readings shall be made on opposite sides, and approximately at the widest portion of the cross-section of the fruit at right angles to the core. Sunburned or very highly colored areas shall be avoided in making pressure tests.

During the first ten days after the beginning of shipments of Bartlett pears from any district or section, any Bartlett pears, from such district or section, which are smaller than two and one-fourth inches in diameter shall not be considered as properly developed.

COLOR CHART

The color plate opposite page 16 is a reproduction of the color charts used for the past three years and now adopted by the Bureau of Fruit and Vegetable Standardization, State Department of Agriculture, as official standards for determining the color requirements of Bartlett Pears.

Color No. 1 (green) represents the original color of the fruit before any "breaking" or lightening appears. Bartlett pears should not be harvested until this color disappears.

Color No. 2 (light green) represents very satisfactory picking maturity, provided the flesh of the fruit does not exceed 23 pounds pressure. At this stage of coloring the darker lenticels on the skin give the fruit a "speckled" appearance.

Color No. 3 (yellowish green) represents the appearance of the fruit from the interior valleys and higher altitudes near the end of the picking season. The firmer type of pears, which ripen with a high color, should correspond to this shade before harvesting.

Color No. 4 (yellow) represents fruits which may be harvested without regard to its firmness.

To secure the most accurate comparison between the color of the fruit and the different shades on the chart, a small circular opening is made in the latter, and the chart then placed immediately over the fruit. In this manner, shades of difference, difficult to detect otherwise, can easily be determined. Comparison should be made with the green or yellow between the lenticels.

The use of the color chart is particularly recommended with fruit which softens slowly but which shows marked changes in color.

THE PRESSURE TESTER

Applying pressure with the thumb has long been a means of determining the softness of fruits. The idea of using a mechanical device to measure softening was first conceived by Morris[6] of the Washington Agricultural Experiment Station in connection with studies on the rate of ripening of apples in storage. The original device of Morris consisted of nothing more than a marble partially embedded in a block of paraffin. This block was placed on the top

[6] Morris, O. M. Studies in apple storage. Washington Agr. Exp. Sta. Bul. 193:1–43. 1925.

of a spring scale, and the fruit was tested by pressing it down on the marble until the surface of the apple touched the paraffin block. The pressure exerted was then read in pounds on the dial of the scale.

Several years later, Murneek[7] of the Oregon Agricultural Experiment Station, developed a more elaborate form of tester, where the fruit was put on a scale and, by means of a lever, a plunger point was forced into the fruit to a given distance. The depth to which this point penetrated was regulated by an electric bell operated from a storage battery.

Later, Magness[8] and Taylor of the United States Department of Agriculture, realizing that such an instrument could not easily be transported from place to place or conveniently used for field tests, designed a much smaller, more simple instrument. This pressure

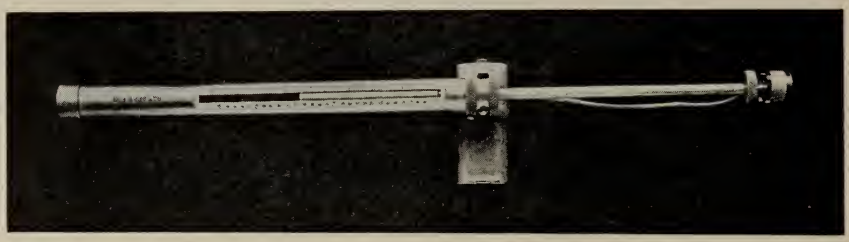


Fig. 3.—The U. S. fruit pressure tester.

tester, often spoken of as the Government or U. S. tester, to distinguish it from the earlier models used in Washington and Oregon, is illustrated in figure 3. In brief, it consists of a metal barrel within which works a plunger attached to the barrel by a steel tension spring. On the end of this plunger is the rounded point that is forced into the fruit. When it has penetrated to a depth of $\frac{5}{16}$ of an inch, electrical connections are made with the small flashlight attachment, and the reading is then taken on the scale of the barrel. Through the use of different-sized plunger points, this tester can also be employed to determine the softness of plums and peaches, as well as that of apples and pears.[9]

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[7] Murneek, A. E. A new test for maturity of the pear. Oregon Agr. Exp. Bul. 186:1–28. 1921.

[8] Magness, J. R., and Geo. F. Taylor. An improved type of pressure tester for the determination of fruit maturity. U. S. D. A., Dept. Cir. 350:1–8. 1925.

[9] *Note:* A plunger point having a diameter of $\frac{5}{16}$ of an inch has been used with peaches and pears and a point of $\frac{7}{16}$ inch in diameter has been used with plums and apples. Much of the experimental data on pears published by the Oregon Agricultural Experiment Station is based upon the use of a ½ inch and $\frac{7}{16}$ inch plunger point, and hence pressures are not comparable with those obtained at this Station or by federal investigators.

The instrument described above has been extensively used in the maturity investigations during the past few years and has given excellent results. It is not, however, without several defects. Its length makes it somewhat unhandy to carry and operate. The small flashlight batteries are in many instances difficult to secure, and unless care is taken each time the instrument is laid down or carried in a car, the ferrule surrounding the plunger point slips back unnoticed, the contact tips complete the electrical connections, and the battery is quickly run down. In making repeated tests on Bartlett pears, where pressures of from 20 to 30 pounds are required, a more suitable handle or grip would be less tiresome to the hand. As the removal of skin from the areas to be tested is desirable a peeling device attached to the tester would also make unnecessary the use of a separate knife in preparing the fruits for testing.

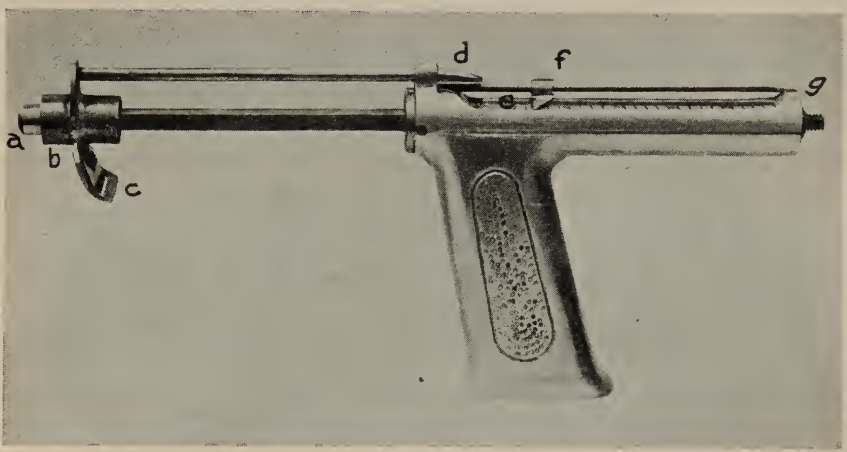

Fig. 4.—California pistol-grip tester. (*a*) Plunger point, (*b*) collar, regulating depth of penetration of the plunger point, (*c*) peeling device, (*d*) indicator, which slides as pressure is applied on (*a*), (*e*) end of sleeve surrounding spring, (*f*) recording rider, (*g*) nut for adjusting tension of spring.

DESCRIPTION OF THE CALIFORNIA TESTER

It is believed that the above defects have been eliminated and that a much more convenient form of tester (illustrated in figure 4) has been developed.[10] In principle, this tester is the same as that designed

[10] The writer is indebted to Professor Eugene G. McKibben, formerly Assistant Agricultural Engineer in the California Agricultural Experiment Station, for making the first experimental model of this instrument. Valuable suggestions regarding its construction were also received from Mr. Arthur H. Hoffman, Associate Agricultural Engineer, California Agricultural Experiment Station, and Mr. C. E. Barbee, Mechanical Technician.

by Magness and Taylor, and as the size of the plunger points and strength of the spring are unchanged, readings on the two instruments are comparable. This new design, however, is of smaller size and lighter weight, and is equipped with a pistol-grip handle.

Another feature considered of great convenience is the peeling device (*c*) beneath and immediately behind the plunger point. This consists of a removable blade duly protected by a metal bar which also serves to regulate the depth of the cut.

The handle of the instrument, as well as the main barrel, is of one-piece cast aluminum, while other parts are of brass and steel. The electrical attachment, used on other instruments to indicate the point at which pressure readings should be made, has been replaced by a sliding indicator (*d*) which operates as pressure is applied to the plunger point. When the plunger point (*a*) has penetrated the flesh to its full depth, this indicator (*d*) is even with the end of the sleeve (*e*) covering the spring. (See figs. 4 and 6.) The rider attachment (*f*) may also be used to record the pressure exerted after the spring has been released. The spring within the barrel is of high-grade piano wire tested for accuracy on a standard scale. The milled cap or nut (*g*) (fig. 4) at the end of the tester provides for any spring adjustment which may subsequently be necessary.

PRESSURE TEST DETERMINATIONS

In most districts of the state, where changes in firmness are more marked than those in color, pressure determinations are believed to be the most reliable and practical maturity test that has been developed. The pressure tester is of simple mechanical construction and can be used either in the orchard or packing house. With a little experience, it can be operated with equal success by growers, packing house men, and fruit inspectors. One should remember, however, that certain factors may influence the readings to some extent, and that these possible influences should not be overlooked. All tests should be made as soon as possible after the fruit is picked and extreme temperatures of the fruit should be avoided.

Operation of the Tester.—With the peeling device located immediately under the plunger point, removal of the skin from the areas to be tested is easily and quickly done with one downward stroke of the instrument (fig. 5). Slightly raising it again brings the plunger point into position for making a pressure determination. The point should be placed squarely over the peeled area, the fruit firmly gripped or placed against something solid, and pressure

applied until the plunger penetrates the flesh to its full depth (fig. 6). This is shown on the tester by the indicator (*d*) coming into juxtaposition with the end of the sleeve (*e*). When this occurs the pressure is released and the reading is recorded by the rider (*f*). It will generally be found, in testing Bartlett pears, that if sufficient pressure is applied to force the plunger point into the fruit in

Fig. 5.—California pistol-grip tester, showing method of removing peeling from the fruit.

Fig. 6.—California pistol-grip tester, illustrating method of making the test and taking the reading.

approximately one second, there will be sensed a very definite "breaking point" or time of penetration. After a little experience in making the tests, one soon learns to read the scale on the tester even without the rider.

Choosing the Sample of Fruit.—A minimum of ten pears should be selected for any official test. The individual fruits should be picked from different trees, or when testing takes place in a packing

house, should be taken from different lug boxes. Different fruits and even the two tests on the same fruit will show some variation in firmness. To avoid unnecessary variation, the ten or more fruits should be of relatively the same color and general appearance. On the other hand, the sample should be typical of the entire lot of fruit to be tested. If this shows considerable variation, the sample should likewise include the various gradations of size and color. In early pickings small fruit may test somewhat firmer than that of medium size, although there appears to be no consistent difference between size and firmness. Specimens larger or smaller than would be picked commercially, windfalls, or fruit showing serious defects or injury, naturally should not be included in the sample.

Points Selected for Making the Test.—The points selected for making the test should be on opposite sides of the fruit at approximately the widest portion of the cross section and at right angles to the core. In selecting these points, sides which may show sunburn or a high color should be avoided as they will test materially higher than the sides showing the usual shade of green. Any part of the fruit which may be affected by frost, hail, scale, or other injury likely to influence the texture of the flesh should likewise be avoided. As the skin of the fruit influences the reading of the pressure tester, this should be removed before making a determination.

Recording and Averaging the Readings.—Twenty separate determinations, two to each pear, are necessary to constitute an official test, and each determination should be recorded as made. Pressure readings can easily be made within one pound, and, in the experimental work, an attempt has been made to record the determinations within one-half pound. After each of the ten fruits has been tested the separate determinations are added and averaged. The necessary division required to obtain the average is easily carried out by dividing the sum of the individual readings by 20, or simpler still, by 2 and moving the decimal point one place to the left.

Expected Variations in Readings.—In making over 350 tests, or approximately 7000 individual determinations, extreme variations between the 10 specimens in a sample have been as high as 8 and 10 pounds. Such variations, however, are rarely encountered. Eighty-three per cent of all tests have shown variations of less than six pounds, while approximately 50 per cent have shown variations of less than four pounds. Three and one-half pounds is the most frequent variation. Although variations between two sides of the same fruit may likewise show a variation of several pounds, 78 per cent of the tests show a variation of only one pound or less.

In most instances when 20 separate determinations are compared, the variations in the different readings are found to largely compensate each other, and the final average represents a very accurate index of the general maturity of the lot. In a few instances, however, where the reading of a single pear may show as much as three pounds variation above or below the *average of the lot,* this fruit should be discarded and one or more additional ones tested in its place.

Growers should ascertain as soon as possible the usual rate of softening, and the relation between certain pressures and the quality which the fruit from their district will be expected to develop. Harvesting of fruit as soon as it will pass the minimum legal restrictions will not, in most instances, insure more than *fair* quality. For fruit of *good* to *very good* quality a delay of from one to two weeks is recommended.

ACKNOWLEDGMENTS

The above investigations have necessitated many tests on pears in various parts of the state and the results herewith presented have been made possible only by the interest and hearty cooperation of numerous growers, fruit shipping associations, and various state and county officials. To all of these the writer wishes to extend his sincere appreciation.

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